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## Extended Workdays in an Underground Mine: A Work Performance Analysis

By J. C. Duchon, C. M. Keran, B. C. Nelson, and T. J. Smith

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**Report of Investigations 9526**

# **Extended Workdays in an Underground Mine: A Work Performance Analysis**

**By J. C. Duchon, C. M. Keran, B. C. Nelson, and T. J. Smith**

**UNITED STATES DEPARTMENT OF THE INTERIOR**  
**Bruce Babbitt, Secretary**

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# **UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT**

ft    foot

min    minute

h    hour

pct    percent

Reference to specific products does not imply endorsement by the U.S. Bureau of Mines.

# **EXTENDED WORKDAYS IN AN UNDERGROUND MINE: A WORK PERFORMANCE ANALYSIS**

**By J. C. Duchon,<sup>1</sup> C. M. Keran,<sup>1</sup> B. C. Nelson,<sup>2</sup> and T. J. Smith<sup>3</sup>**

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## **ABSTRACT**

The use of extended workdays or compressed workweeks (regular shift lengths exceeding 8 h) is attracting growing interest in many industries using continuous operations. While extended workdays promise increased worker satisfaction due to more days off, including weekends and holidays, there are legitimate concerns about the potential effects on the health and safety of such a schedule.

The U.S. Bureau of Mines (USBM) conducted a study at a Canadian underground copper, lead, and zinc mining operation that was designed to study the safety and performance implications of extended workdays. Measures were taken before and after a change from the old 8-h continuous schedule to the new 12-h continuous schedule, including behavioral performance measures to analyze perceptual-motor changes, continuous heart-rate monitoring and aerobic capacity to measure physical fatigue, a variety of self-report questionnaires to measure perceived adaption and satisfaction with the new schedule, and pulmonary-respiratory measures to examine air contaminant exposure.

Based upon the overall acceptance of the new schedule by the workers and lack of change in fatigue-sensitive behavioral and physiological performance measures, this study recommends that the mine retain the 12-h schedule. However, certain precautionary measures are suggested to insure the safety of the workers.

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<sup>1</sup>Engineering research psychologist.

<sup>2</sup>Mining engineer.

<sup>3</sup>Group supervisor.

U.S. Bureau of Mines, Twin Cities Research Center, Minneapolis, MN.

## INTRODUCTION AND OVERVIEW

The use of extended workdays (shift lengths exceeding 8 h) is attracting growing interest in mining operations. A substantial portion of the requests for information and assistance from mining companies received in 1989 through 1991 by shiftwork researchers at the USBM related to extended workday issues.

The USBM is an agency within the U.S. Department of the Interior mandated to conduct research to ensure the continued viability of mineral resource production in the United States. Extended workday research was part of a research project on shiftwork in mining conducted by the Human Factors Group at the Twin Cities Research Center. This research was conducted to examine potential safety implications of shiftwork.

Extended workday schedules generally are more widespread in surface than in underground mining operations in North America. In the United States, there are no federal or state mining regulations governing the length of the workday. In Canada, each Province defines its own rules governing extended shifts in underground mining.

In September 1988, the Mining Legislative Review Committee (MLRC) within the Ministry of Labour for the Province of Ontario established an Hours of Work Subcommittee. A 1989 report issued by this subcommittee makes three salient points with regard to extended workdays in underground mining (1).<sup>4</sup>

1. As of 1989, nine Canadian provinces and territories limit hours of work underground to 8 h out of 24 h. Newfoundland and Quebec have no regulations governing hours of work underground, and there is no report for Prince Edward Island. In 1989 outside of Quebec, the report specified 25 underground mines in Canada for which exemptions have been granted to allow extended workdays (9-12 h per shift). Quebec is reported to have a number of underground mines with extended workdays. In both British Columbia (B.C.) and Ontario, an underground mining operation wishing to introduce extended workdays must petition the provincial government for an exemption, which typically is granted only to operations classified as remote.

2. The report identifies the following potential issues associated with the introduction of extended hours of work underground: (1) more layoffs; (2) greater physical and mental fatigue, causing increase in accidents; (3) adverse effects on health, caused by longer exposure per shift to airborne particulates, job stress, and poor viewing conditions linked to eyesight problems; (4) challenges to mining regulations; (5) improved quality of life; (6) improved operational efficiency; (7) reduced absenteeism; (8) improved work attitude; (9) reduced commuting problems; and (10) assist in skill shortages.

The first four of these issues represent possible adverse effects, the remainder possible benefits, arising from introducing extended workdays underground.

3. Based on this analysis, the report recommends that the Ontario Ministry of Labour should consider longer hours of work when designing-revising occupational health and safety regulations. Further research on the problem of extended workdays underground also is advocated.

As implied by the latter point, when it comes to making decisions about extended workdays in mining one of the major problems confronting both mine operators and government mining regulators is the essential lack of definitive information about possible negative or positive effects of extended workdays on the safety, health, and performance of the mineworker and the operation generally. This point is supported by a review of the literature of extended workdays which indicates a lack of consensus among studies and a need for more research (2). The purpose of the present study is to explore these issues at a mining company, and to thereby benefit decision-making by those considering the introduction of extended workdays into mining operations. To achieve this objective, this study is designed to collect objective and subjective performance data from an underground metal mine before and after a group of miners changed from an 8- to a 12-h rotating shift schedule.

## BACKGROUND OF STUDY

Westmin Resources Limited headquartered in Vancouver, B.C. operates a large underground metal mine producing primarily copper, zinc, and lead at its Myra Falls Operations in the Strathcona Wilderness Park on

Vancouver Island, about 100 km southwest of Campbell River, B.C. Both mines at the site are operated continuously on a 24-h basis. Ore is mined and beneficiated at the Myra Falls site, and then conveyed via a haulage truck fleet to ocean shipping docks in Campbell River.

In 1989, Westmin Myra Falls Operations first contacted the British Columbia Ministry of Energy, Mines, and

<sup>4</sup>Italic numbers in parentheses refer to items in the list of references at the end of this report.



Petroleum Resources (BCMEMP) about introducing extended workdays for a group of underground workers employed by the H-W mine at the Myra Falls site. The H-W mine is the larger of the two mines at the site. As noted above, under provincial law underground mines in British Columbia wishing to introduce workdays longer than 8 h must apply to the BCMEMP for an exemption.

Also in 1989, the USBM was completing a two-phase, prospective extended workday study of underground workers at an underground gold mine in Ontario that had changed from 8- to 10-h shifts. The Ontario study was conducted under the auspices of a Cooperative Agreement between the USBM and CANMET (the Canadian Center for Mineral and Energy Technology, a mining, mineral, and energy research agency within the Canadian Ministry of Energy, Mines, and Resources). In particular, a Supplemental Agreement and Addendum to the USBM-CANMET agreement was developed for the Ontario study to deal specifically with extended workday research. The Supplemental Agreement made possible a cooperative extended workday research effort involving the USBM, CANMET, the Ontario Ministry of Labour, and the mining operation. Findings from the Ontario extended workday study are summarized in publications by Hudock (3-4), Smith (5) and Wagner (6).

Because of their involvement with the Ontario project, USBM shiftwork researchers were invited by BCMEMP to design, organize, and conduct an extended workday study at the Westmin Myra Falls Operations. To address uncertainties associated with use of extended shifts underground (above), the study was conceived by the Ministry as a condition for approval of a company request to change a group of workers (the experimental group) employed on the tramming and crushing levels (levels 2400 and 2500) of the H-W mine from 8- to 12-h shifts (level 2400 is 1,927 ft below surface).

A primary impetus for the company request was pervasive unhappiness among the experimental group regarding the 7x3 (7 days on, 3 off), 7x2 (7 nights on, 2 off), 7x2 (7 afternoons on, 2 off), 8-h shift rotation schedule, which allowed few holidays and weekends off. Hereafter, the term "level 2400 workforce" will refer to the experimental group, along with a control group of workers also employed on level 2400 of the H-W mine who remained on 5x2 (5 days on, 2 off) 8-h shifts for the duration of the study.

A planning meeting, at the minesite in March 1990 among project cooperators, produced an agreement that the study would proceed under the auspices of the existing USBM-CANMET agreement. Information presented during the meeting suggested that as a consequence of broad unhappiness with the 8-h rotation schedule, the level 2400 workforce had more safety problems, higher turnover, lower morale, higher absenteeism, and lower job training and experience than any other level in the mine.

In broad agreement with mining extended workday issues targeted by the Ontario Ministry of Labour MLRC Hours of Work Subcommittee (above), there was a general consensus among representatives at the planning meeting that introducing 12-h shifts for the level 2400 workforce at the H-W mine would have both positive and negative effects. Benefits anticipated included: (1) projected improvements in family, social, and recreational life (due to more days off between work periods), employee morale, labour relations, production efficiency, and commuting safety; (2) projected reductions in accidents, absenteeism, commuting time, turnover, and substance abuse (12-h shiftworkers stay at minesite where alcohol is prohibited); and (3) more experienced workers likely to bid on level 2400 jobs, leading to reduced training needs for crew personnel.

The two most significant potential risk factors identified at the planning meeting of 12-h shifts underground were (1) increased likelihood of vigilance problems (due to physical and mental fatigue) and (2) longer workday exposure to airborne particulates.

Issues of commuting played a central role in these extended workday deliberations. Most workers employed at the Westmin Myra Falls site live in Campbell River, about 100 km from the mine. Some workers drive, but most use the bus service that the mine provides. Commuting time is about 80-90 min by bus. With round-trip commuting time factored in, the elapsed workday time for a typical mineworker on an 8-h shift thus averages 11.5 to 12 h.

Because of the lengthy commute, the BCMEMP mandated that the mine provide on-site lodging and meals for all workers on 12-h shifts. This provision has positive and negative implications. It reduces the number of commuting trips and thus improves commuting safety. Prohibition of alcohol on site may also reduce substance abuse problems. At the same time, lodging workers on site represents an increased cost to the mine.

As noted above, the planning meeting projected two seemingly contradictory effects of 12-h shifts: reduced on-the-job accidents, but increased behavioral fatigue and vigilance problems. This underscores the uncertainty surrounding the actual consequences of introducing extended workdays into a mining operation.

The broad purpose of the research described in this report is to address serious concerns raised by management, workers, unions, and various governmental policy makers that the added behavioral and physical fatigue of working 10- or 12-h days may create an increased risk of accidents, errors, and health problems (7-8). To this end, the study evaluates the consequences of replacing a traditional 8-h rotating shift with a new 12-h extended workday schedule for a group of workers employed at an underground mine.

## METHOD

### RESEARCH DESIGN

Data were collected on site in two phases from a group of workers employed at an underground metal mine in western Canada.

#### Phase 1 of study

Two groups of subjects were evaluated over a 10-day period in May 1990. The experimental group consisted of three seven-man crews, each working a backward rotating 7x3d, 7x2n, 7x2a (7 days on, 3 off, 7 nights, 2 off, 7 afternoons, 2 off) 8-h shift schedule. The control group consisted of workers on a 5x2 (5 days on, 2 days off) straight day, 8-h shift schedule. This group remained on the 8-h shift schedule during both phases of the study.

Yates' corrected chi-squared test of independence was performed on three self-reported responses to questions regarding the difficulty of each subject's job. Responses to these five-point scales indicated how physically demanding, mentally demanding, and stressful their job was. In each case, statistical significance was not reached at the 0.05 level. This indicates that the work performed by the experimental groups and control groups was comparable with regard to these three dimensions. For all groups combined 24.4 pct indicated "heavy" or "very heavy" physical demands, 53.3 pct "moderate" demands, and 22.2 pct "light" or "very light" demands. Responses to how mentally demanding and stressful the job was, showed similar distributions.

Data collection was carried out around-the-clock and throughout the work week. Collection was concentrated at the start-of-shift, 4 h-into-shift, and end-of-shift. All subjects took their tests within 1 h or less of this schedule. Owing to scheduling and time constraints, the 7x2 day crew was only studied for the last 5 days of their shift period, days 3 to 7.

#### Phase 2 of study

In July 1990, the mine introduced a 4x4 12-h shift schedule (4 days on, 4 days off, rotating between days and nights) for the experimental subjects evaluated during phase one. Owing to a provincial government requirement, all 12-h workers remained on site for the duration of their 4 day workweek (most workers had a 3-h round trip commute from home).

The second phase of the study was carried out over a 9-day period, 10 months after phase one. Data collection during phase two was carried out around-the-clock and throughout the workweek, with collection concentrated at the start-of-shift, 4 h-into-shift, 8 h-into-shift, and end-of-shift for the 12-h subjects.

### SUBJECTS

All subjects were male. Subjects were excluded from the analysis when (1) the data were less than 67 pct complete; and/or (2) missing data were nonrandom in nature (i.e., 2 full days of data missing out of seven 8-h days). Based on these criteria, a total of 31 experimental and 10 control subjects contributed to this study. The number of subjects used in any particular analysis will be discussed below.

The mean age (in years) for the experimental subjects was 35.6 (range 21-62,  $N = 31$ ) and for the controls 34.8 (range 28-50,  $N = 10$ ). Ethical criteria adopted by the U.S. National Research Council for the use of human subjects in research were adhered to.

#### Data Collection Procedures

Consistent with theoretical models of fatigue, this study uses three dimensions that measure the effects of fatigue. These are behavioral performance, subjective response, and physiological functioning.

#### Subjective Mood Measures

To measure possible decrements in worker mood and behavioral performance, a computerized behavioral battery was employed, adapted from a more extensive version developed by National Institute for Occupational Safety and Health (NIOSH) (9). The first part of the battery consisted of seven self-report mood scales, resulting in three mood indices, Agreeable, Think Clearly, and Energetic, plus the Stanford Sleepiness Scale (SSS) (10).

#### Behavioral Performance Battery

The second part of the battery consisted of five behavioral performance tasks. Owing to time constraints practice was not possible. Therefore, practice effects were anticipated and are discussed later. The behavioral performance tasks are—

(1) Tracking. Pursuit tracking (2-min trials) was performed using a joystick to control the vertical position of a tracking cursor with constant horizontal velocity (30 sweeps per minute) by centering it on a stationary sinusoidal target band. The performance measure is root mean square (RMS) error for the trial.

(2) Grammatical reasoning and (3) Dual grammatical reasoning. In the nondual grammatical reasoning task, a logical statement was displayed, and the subject was required to indicate whether the statement was true or false. In the dual task, the subject was required to respond to

the logic statements and also to randomly presented noise tones.

(4) **Choice reaction time.** This task required the subject to depress the appropriate button when the word "true" or "false" appeared on the monitor.

(5) **Tapping.** The tapping task was performed by alternately depressing two buttons as quickly as possible for 1 min.

### Ergometry

Using Monark bicycle ergometers (Ergomedic Model 818E), each subject was administered submaximal exercise tests at the start and end of their shift day, using a protocol (three successive 4-min work loads) adapted from the original procedure developed by Åstrand and Rhyming (11). Those subjects reporting exercise risk problems on a health screening questionnaire were excluded from testing.

Estimated maximal aerobic capacity ( $VO_{2max}$ ) levels for the subject were derived using the Åstrand and Rhyming (11) nomogram. The measure reported is the maximal oxygen consumption per unit body weight ( $VO_{2max}$  per kilogram), in milliliter of  $O_2$  per minute per kilogram.

Percent heart rate (HR) recovery levels at 1 and 2 min after cessation of submaximal exercise were calculated as follows:

PR-1 {PR-2}

$$= \frac{([HR-R1] \{HR-R2\} - (HR-UL)) \times 100}{[(HR-WL3) - (HR-UL)]}$$

PR-1 and PR-2 refer to the percent HR recovery at 1 and 2 min. HR-R1 {HR-R2} is the HR level recorded at 1 {2} min of recovery, HR-UL is the HR after 2-min unloaded peddling (recorded before the first workload), and HR-WL3 is the HR recorded at the end of 4 min at the highest work load.

### Work, Food, and Sleep Diary

The diary was developed by the USBM to collect information from shift workers on a daily basis. Five diary responses were used in this study: frequency of health complaints, number of sleep episodes, how sleepy prior to sleep episode, how well slept and how rested after sleep episodes, and total daily sleep length. Total sleep length is defined as the sum of time devoted to all sleep episodes, less sleep latency (the length of time it takes to fall asleep), and less time spent during any awakenings reported.

### Continuous HR Monitoring

Continuous records of working HR levels across the shift were obtained from every subject on every workday

during their data collection periods. For this purpose, Polar Vantage XL heart rate monitors (Polar USA, Inc.) were employed.

### Shiftwork Survey Questionnaire

This is a USBM-developed questionnaire aimed at collecting information about worker experience with, acceptance of, and complaints about, the shiftwork schedule (12). This was administered once per phase.

### Statistical Analysis

For both the control and experimental groups, four multivariate analysis of variances (MANOVA's) were performed, each dealing with a unique set of dependent variables: (1) the four mood indices, (2) the five performance tasks, (3) the three ergometric measures, and (4) the six diary items. Refer to table 1 for the n of cases and number of unique subjects used in phase one and phase two for each analysis.

**Table 1.—Number of cases who contributed to each MANOVA within each shift group**

	Self-report measures	Performance tasks	Ergometry measures	Diary items <sup>1</sup>
<b>EXPERIMENTAL GROUPS</b>				
Phase 1:				
7x2d .....	5	4	5	8
7x2a .....	6	5	5	12
7x2n .....	5	5	5	9
Phase 2:				
4x4d .....	12	8	9	10
4x4n .....	12	7	7	11
Totals cases <sup>2</sup> .....	40	29	31	23
Repeat subjects <sup>3</sup> ..	12	8	8	6
Nonrepeat subjects <sup>4</sup>	16	13	15	11
<b>CONTROL GROUPS</b>				
Phase 1: 5x2d ....	8	5	5	4
Phase 2: 5x2d ....	6	3	5	6
Total cases <sup>2</sup> .....	14	8	10	10
Repeat subjects <sup>3</sup> ..	4	3	2	2
Nonrepeat subjects <sup>4</sup>	6	2	6	6

MANOVA Multivariate analysis of variance.

<sup>1</sup>Diary data from some subjects were collected on multiple shifts within each phase.

<sup>2</sup>Total cases, which comprise repeat and nonrepeat subjects, are the number of cases used in each MANOVA.

<sup>3</sup>Repeat subjects contributed to both phases of each MANOVA. Therefore each of these subjects contributed two cases. Because of missing data, attrition, and new hires, the number of repeat subjects does not match total cases.

<sup>4</sup>Nonrepeat subjects contributed to either phase 1 or phase 2 of each MANOVA. Therefore each subject contributed one case.

For the control group a mixed design MANOVA was performed for each set of dependent variables. There was one between subjects factor: phase (phase one versus phase two), and two within subject factors: day (day-into-shift) and session (time-into-shift).

A mixed design MANOVA was also performed for the experimental group for each set of dependent variables. There was one between subjects factor, shift, with five levels, representing the 7x2d, 7x2a, 7x2n, 4x4d, and 4x4n shifts. There were two within subject factors: day and session. The four levels of day included days 1, 3, 5, and 7 for the 8-h subjects and days 1, 2, 3, and 4 for the 12-h subjects. The four levels of session included sessions 1, 2,

and 3 for the 8-h subjects and sessions 1, 2, 3, and 4 for the 12-h subjects. Since the 8-h subjects only had three sessions, a fourth session was added and given the value for the third testing session. Since the 7x2d group missed day 1, the value of day 3 was used. These modifications tend to make tests of significance more conservative.

For each significant MANOVA effect, a post hoc analysis of variances (ANOVA) was performed to determine the specific dependent variable contributing to the significant effect. Significance was set at  $p < 0.05$  for all statistical tests. Data from the Shiftwork Survey were not statistically analyzed.

## RESULTS

### CONTROL GROUP

MANOVA results from the three mood indices plus the SSS indicate only a significant main effect for day,  $F(16, 192) = 1.83$ ,  $p < 0.05$ . Post hoc ANOVA's on the four measures reveal that thinking clearly,  $F(4, 48) = 4.65$ ,  $p < 0.01$  and feeling agreeable,  $F(4, 448) = 2.75$ ,  $p < 0.01$ , are significantly related to days of the work week, i.e., days four and five are associated with improved mood. The shift effect is not significant, indicating that there are no differences for the four scales between phase one and phase two. Similarly, the performance tasks, ergometry measures and Diary items are not associated with significant effects. Only the MANOVA associated with the performance task for the day effect "approaches" significance ( $p = 0.053$ ). Post hoc ANOVA's indicate a presumed learning effect for the dual grammatical reasoning ( $p < 0.05$ ), grammatical reasoning ( $p < 0.06$ ) and tracking task ( $p < 0.05$ ).

### EXPERIMENTAL GROUP

Table 2 summarizes experimental group MANOVA results for the self-report, behavioral performance tasks, ergometry, and diary data.

#### Self-Report Mood Indices

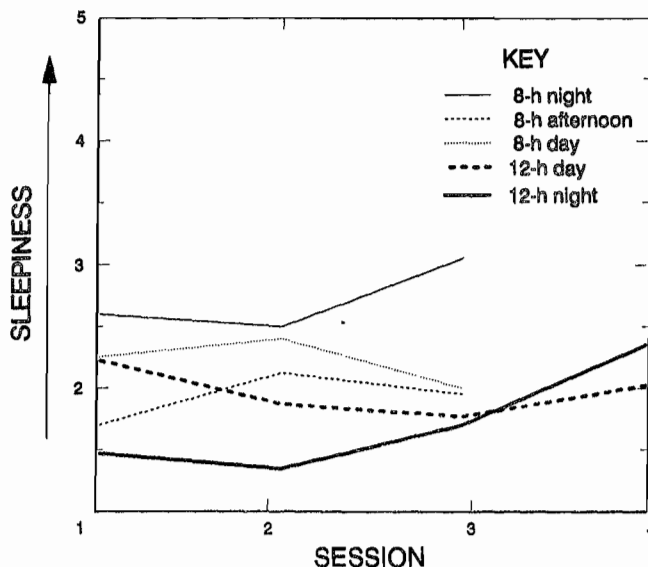
MANOVA results for the three mood indices and the SSS are shown in table 2. The primary finding is the significant shift X session interaction,  $F(48, 420) = 1.96$ ,  $p < 0.001$ . Post hoc ANOVA's performed on each dependent measure indicate that each of the four measures contribute to the significant interaction. Results for the SSS and Energetic scales indicate that respondents on both the 8- and 12-h night shifts report more sleepiness and tiredness 8-h into the shift, compared to the beginning of

the shift (see figure 1 for the SSS). Sleepiness and tiredness, as indicated by these two scales also increased at the end of the shift on the 12-h shift. Results for the other mood indices, feeling agreeable and thinking clearly, indicate that workers on the 8-h day shift report lowered mood at the beginning of shift, compared to the other groups.

#### Performance Measures

Table 2 shows significant MANOVA effects for the performance measures derived from the behavioral

Figure 1



Changes in Stanford Sleepiness Scale self-report responses on behavioral battery for experimental subjects, by shift group and session.

Table 2.—MANOVA and post hoc ANOVA results for experimental groups

(Values in parentheses are degrees of freedom)

	Shift	Day	Session	Shift x day	Shift x session	Day x session	Shift x day x session
SELF-REPORT MEASURES							
MANOVA—Pillai's F	<sup>1</sup> 2.05 (16,140)	<sup>1</sup> 1.89 (12,312)	1.60 (12,312)	1.13 (48,420)	<sup>2</sup> 1.96 (48,420)	1.38 (36,1260)	1.21 (144,1260)
Post hoc ANOVA:							
Agreeable . . . .	1.45 (4,35)	1.02 (3,105)	NAP	NAP	<sup>2</sup> 3.27 (12,105)	NAP	NAP
Think clear . . . .	1.62 (4,35)	<sup>2</sup> 4.69 (3,105)	NAP	NAP	<sup>2</sup> 2.55 (12,105)	NAP	NAP
Energetic . . . . .	<sup>1</sup> 3.45 (4,35)	<sup>2</sup> 6.23 (3,105)	NAP	NAP	<sup>2</sup> 3.74 (12,105)	NAP	NAP
SSS . . . . .	2.57 (4,35)	0.39 (3,105)	NAP	NAP	<sup>2</sup> 2.67 (12,105)	NAP	NAP
PERFORMANCE TASKS							
MANOVA—Pillai's F	1.22 (20,92)	<sup>2</sup> 5.13 (15,210)	<sup>2</sup> 2.39 (15,210)	<sup>2</sup> 1.59 (60,360)	<sup>1</sup> 1.50 (60,360)	<sup>2</sup> 1.78 (45,1080)	1.18 (180,1080)
Post hoc ANOVA:							
Dual GR . . . . .	NAP	<sup>2</sup> 7.69 (3,72)	0.87 (15,210)	0.45 (12,72)	0.80 (12,72)	1.44 (9,216)	NAP
GR . . . . .	NAP	<sup>2</sup> 10.88 (3,72)	0.98 (15,210)	0.88 (12,72)	1.44 (12,72)	0.99 (9,216)	NAP
Choice RT . . . .	NAP	0.45 (3,72)	1.82 (15,210)	0.92 (12,72)	0.88 (12,72)	0.64 (9,216)	NAP
Tracking . . . . .	NAP	<sup>2</sup> 34.10 (3,72)	<sup>2</sup> 10.21 (15,210)	<sup>2</sup> 4.94 (12,72)	<sup>2</sup> 5.36 (12,72)	<sup>2</sup> 4.58 (9,216)	NAP
Tapping . . . . .	NAP	1.55 (3,72)	2.53 (15,210)	<sup>2</sup> 2.64 (12,72)	1.80 (12,72)	1.22 (9,216)	NAP

ANOVA Analysis of variance.  
 GR Grammatical reasoning.  
 MANOVA Multivariate analysis of variance.  
 NAP Not applicable.

RT Reaction time.  
 SSS Standard sleepiness scale.  
<sup>1</sup>p < 0.05.  
<sup>2</sup>p < 0.01.

battery. The main effects of day,  $F(15,210) = 5.13$ ,  $p < 0.01$ , and session,  $F(15,210) = 2.39$ ,  $p < 0.01$ , are significant. However, only the higher order significant interaction effects of Shift X Day,  $F(60,360) = 1.59$ ,  $p < 0.01$  and Shift X Session,  $F(60,360) = 1.50$ ,  $p < 0.05$ , will be discussed.

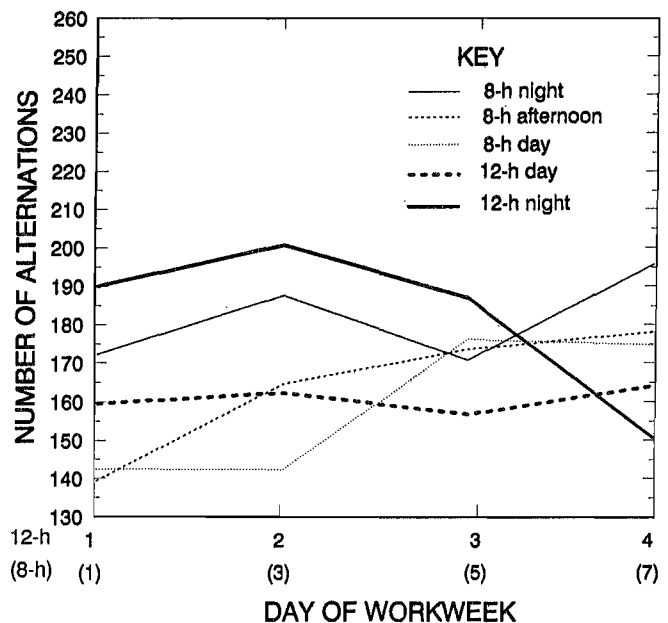
Post hoc ANOVA's for each dependent measure on the Shift X Day effect reveal that only the tracking and tapping task are significant. Interpretation of the tracking results is complicated because of the apparent occurrence of a learning curve for task performance. Several trials on the task appear to be required before proficiency is achieved. This is suggested by the significant day effect. While each shift group improved tracking performance (lower RMS error scores) across the work week (probably due to learning), the Shift X Day interaction is related to the 8-h day and night groups starting the week with reduced performance relative to the other groups, whereas the 12-h night group both started and ended the week at performance levels better than the other groups. The significant Shift X Session effect,  $F(12,72) = 5.36$ ,  $p < 0.01$ , reflects relatively consistent RMS scores across the 8- and 12-h workday, except for the 8-h day shift, which is associated with relatively poorer RMS scores on the first session and gradual improvement across the day.

The Shift X Day interaction for the tapping task (frequency of tapping alternations),  $F(12,72) = 2.64$ ,  $p < 0.01$ , indicates that scores either improve or remain stable across the workweek, except the 12-h night shift that reflects a dramatic decrease in tapping frequency on the last (fourth) day of the workweek (figure 2).

## Ergometry

The MANOVA associated with the three ergometric measures shows only a significant Shift X Session interaction,  $F(12,78) = 1.94$ ,  $p < 0.05$ . Post hoc ANOVA's for

Figure 2



*Changes in tapping task responses on behavioral battery for experimental subjects, by shift group and day.*

this effect reveals that only the  $\text{VO}_{2\text{max}}$  results are significant,  $F(3,24)=4.16$ ,  $p<0.05$ . This result stems from an improvement in estimated  $\text{VO}_{2\text{max}}$  levels from start to end of shift for subjects in the 12-h night shift group, an effect that is not observed for subjects in the other four shift groups.

### Work, Food, and Sleep Diary

The MANOVA for the six diary items reveals no significant main or interaction effects. No post hoc tests were performed. The average total sleep length is 7.4 h for the three 8-h shift groups, and 7.6 h for the two 12-h shift groups. For all shift groups combined, the most frequent health symptom reported (as percent of total responses) is "muscle aches" (19.3 pct), followed by "upset stomach" (14 pct) and "back pain" (13.5 pct).

### Shiftwork Survey Questionnaire

Several survey questions inquire about shift preferences. One question asks for the main reason that a respondent would change jobs: 38 pct of the 8-h respondents reported "to work different hours," while none of the 12-h respondents gave this response. When asked if they prefer the extended workday schedule, 80 pct of the 12-h respondents reported that they preferred working a 12-h schedule, as opposed to an 8-h schedule. Only one 12-h respondent preferred the original 8-h 7x3,7x2,7x2 schedule.

Further evidence for overwhelming support for the extended workday schedule is indicated by the following responses of 12-h respondents to specified survey questions. With the new extended workday schedule: 100 pct indicated that absences either decreased or stayed the same; 80 pct reported that the new schedule increased morale positively; 85 pct reported the same or fewer health problems; 100 pct reported the same or less amount of stress; 77 pct reported improved eating habits; 93 pct reported the same or improved family life; 100 pct reported the same or better sleep quantity; and 92 pct reported the

same or improved sleep quality. All respondents reported that they became accustomed to the new 12-h schedule within 1 month after the change occurred, and that they were satisfied with lodging at the mine for their workweek.

There also are some negative reactions to the extended workday schedule brought out by answers of some 12-h respondents to survey questions. Although these reports are in the minority, they should be considered. For example, with the 12-h schedule: two respondents reported "more health problems;" seven reported that they were just as tired or more tired in the last 2 h of the 12-h schedule, compared with the 8-h schedule; one person reported that the schedule worsened family life; three reported a worsening of eating habits; two reported a worsening of child care problems; and one reported a worsening of time for recreation and hobbies. One survey question dealing with sleep quality following night shift work also revealed problems with the new schedule: 47 pct of the 8-h night shift respondents reported difficulty staying asleep, versus 54 pct of the 12-h night shift respondents.

### Working Heart Rate Levels

Results for working heart rate levels across the shift for the 8- and 12-h subjects, averaged across all shift groups and all days of the shift period, were analyzed. Mean levels for hours 2-3 (early in shift for 8-h and 12-h subjects), hours 6-7 (late in shift for 8-h, mid-shift for 12-h, subjects), and hours 10-11 (late in shift for 12-h subjects) into the shift were computed. The 8-h data are based on 98 records collected from 20 experimental subjects during phase one. The 12-h data are based on 83 records collected from 22 experimental subjects during phase two.

The mean working heart rate levels range from a high of 101.2 beat per minute (bpm) ( $sd = 12.6$ ) for the 8-h subjects at hours 2-3, to a low of 91.6 bpm ( $sd = 12.0$ ) for the 12-h subjects at hours 10-11. Mid- and late-shift HR levels for the 12-h subjects are lower than early- and late-shift levels for the 8-h subjects. However, these differences are not statistically significant.

## DISCUSSION AND CONCLUSIONS

This study was designed to assess possible fatigue-related performance effects associated with working compressed workweeks and 12-h workdays in an environmentally and physically stressful workplace, namely an underground mine. There currently is little information available from any industrial sector which allows an objective prediction of possible risks and benefits associated with the use of extended workdays.

The study has relied upon a multidimensional approach to fatigue, consistent with models which consider fatigue to be measurable in three basic domains: behavioral performance, physiological function, and subjective response (13). As in any field study the determination of causality is difficult. However, results for the control group employed in this study (i.e., lack of significant phase effects for the dependent measures) suggest that significant



differences observed for the experimental group between phase one (8-h schedule) and phase two (12-h schedule) are due to the change itself and not to other extraneous variables. It should be emphasized however that both occupational (i.e., length of shift) and nonoccupational (i.e., on site lodging, less commuting) consequences of the change may have contributed to the effects observed.

Also, caution should be taken in drawing generalizations from this study due to the statistical violations associated with the methods and analyses. Owing to missing data, attrition and new hires certain modifications in the analysis were needed. The five levels of shift (three 8-h and two 12-h groups) were treated as an independent group factor, when in reality there was overlap of cases. This design would not allow for a purely within subject design without losing over 50 pct of the data.

In general, the findings from this study do not provide a smoking gun to implicate the 12-h schedule as a distinctive fatigue risk. The Shift X Session or the Shift X Day interactions are the effects that would reveal differences in performance for the 12-h shifts. As shown in table 2, only the mood indices show a consistent manifestation of fatigue on the 12-h night shift. However, no other Shift X Session effects indicate a performance decrement across the 12-h shift. The only other suggestion of a negative effect of the 12-h shift was a significant decrement in tapping performance on the last day of the workweek, day four (figure 2).

Performance results from the behavioral test battery must be interpreted with caution for at least two reasons. First, due to the practice effects across the workday, workweek, and possibly between phases 1 and 2 of the study, it is difficult to delineate specific causes of improved performance. This is especially true for the tracking and grammatical reasoning tasks, since they are the most difficult to master.

For example, a possible decremental effect of cumulative fatigue on task performance across the workweek may be offset by learning, such that performance levels remain unchanged or perhaps even improve during the week. However, we can be more confident in interpretation when *decreases* in performance for a given behavioral task are observed, since it can be assumed that practice will only serve to *increase* scores on the task.

Another problem in interpretation of objective results from the behavioral battery is that there may be appreciable individual differences in skill levels among subjects in performing different tasks. This complicates direct comparison of different shift groups, since they are composed of different workers with different inherent abilities. Within each shift group however, the day-into-shift and session effects are based upon repeated measures for each subject. Therefore, these effects are not dependent upon the variability in skill levels between workers, but rather

on changes within subjects performance during the work-day and/or across the workweek.

There are no significant shift effects for the maximal aerobic capacity estimates and HR recovery measures derived from submaximal exercise testing, a result which appears to imply that 12-h shifts are no more physically fatiguing than 8-h shifts.

Whereas sleep length and sleep quality is comparable for both the 8- and 12-h schedules, 30 pct of the subjects reported in the diary that on the 8-h afternoon and night shifts they woke up because of noise or "...even though still tired," whereas none of the 12-h subjects reported this. These differences probably are attributable to lodging by the 12-h workers at the minesite during the work period.

Improved sleep quality can influence performance in a positive way on subsequent shifts. This may in part be the reason why among the 12-h subjects, subjective self-reports of feelings were relatively consistent and objective behavioral performance tended not to decrease across the shift.

The results of this study suggest that the extended workday schedule for the workforce involved should be retained. The rationale for this conclusion is (1) overwhelming support by the workforce for the 12-h schedule, as evidenced by responses to the shiftwork survey questionnaire; (2) survey responses indicating positive effects of the new schedule on absenteeism, morale, health problems, stress, eating habits, family life, and sleep quantity and quality; (3) on all but one objective measures of behavioral performance (the tapping task), 12-h shifts are not associated with decreased performance; and (4) physiological measures do not show indications of physical fatigue associated with 12-h shifts.

While we recommend retaining an extended workday schedule, the following points should be considered.

1. Lodging 12-h workers on site probably influenced results. This is based on the following observations: (1) improvement in sleep quality for the 12-h relative to the 8-h subjects was most likely due to better sleeping conditions associated with minesite lodging, with reduced distractions from family, recreation, entertainment, and commuting factors; and (2) that behavioral performance either remained the same or improved on 12-h shifts may be due to positive sleep behaviors, because sleep hygiene is critical to alertness and general well-being.

2. Adjustment to extended workdays displays individual differences. The bases of this conclusion are (1) the survey questionnaire revealed some negative responses to the 12-h schedule; (2) one survey question dealing with sleep quality on the night shift revealed more reports of difficulty staying asleep among 12-h (53.8 pct) versus 8-h (47.1 pct) night shift respondents; (3) reports of minor

aches and pains as the workweek goes on increased from 11.8 pct among 8-h, to 14.3 pct among 12-h, night shift respondents; and (4) subjective evidence of fatigue on 12-h night shifts is shown by consistently more negative self-reports of feelings towards end of shift in behavioral battery and diary responses by 12-h night subjects.

3. Break schedule for extended workdays should be customized. The bases for this conclusion are (1) mood indices indicated progressively more fatigue throughout the 12-h day; (2) performance levels for the one behavioral task dependent upon physical endurance (tapping) decreased at the end of the workweek; and (3) the survey indicates that some employees report more fatigue during the last few hours of the extended workday. A break schedule customized for 12-h shifts, or periodic assignment

of mentally challenging or light physical tasks, may lessen possible fatigue among 12-h night shift workers.

4. Reevaluate extended workday effects at periodic intervals. This study does not provide definitive answers to all of the questions pertaining to the use of extended workdays in underground mining operations. In light of uncertainties that remain about use of extended workdays in mining and other industries, it seems reasonable to suggest that those on extended workday schedules be reevaluated at periodic intervals. One approach which we have employed involves use of a short questionnaire to elicit worker responses about their schedule (11), coupled with monitoring of company records pertaining to absenteeism, safety, and productivity for workers on extended workday schedules.

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